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Diagnosis Of the Diabetes Mellitus disease with Fuzzy Inference System Mamdani

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ABSTRACT. Patients diabetes mellitus increased from year to year. This is due to delays in diagnosis of the disease and also because of unhealthy lifestyles. This study aims to create an application of decision support systems in the field of health, namely the diagnosis of the Diabetes Mellitus disease with Fuzzy Inference System (FIS) Mamdani, so that a layman can perform early diagnosis and immediate treatment. Decision Support System Techniques developed to improve the effectiveness of decision-makers. Samples are six Puskesmas in East Jakarta. This application uses five variables as inputs consisting of glucose 2 hours after a meal, Diastolic blood pressure, body mass index, family history of diabetes. the number of pregnancies and one variable as output. The data obtained will be processed using fuzzy logic approach to programming matlab and made Graphical User Interface (GUI). The result is an expert system for diagnosis of Diabetes Mellitus by using Fuzzy Inference System (FIS) Mamdani method, obtained an accuracy rate of 95%. It is to help improve the quality of service in the Puskesmas in East Jakarta, thus satisfying the users and Puskesmas be able to compete both nationally and internationally.

1. Introduction

Methods of artificial intelligence (AI) is very widely used in all sectors, including applications in health / medicine. Soft computing technology is an interdisciplinary sector of research study in computational science and artificial intelligence. Some techniques of soft computing, namely expert systems, neural networks, fuzzy logic, and genetic algorithms many developed because it has advantages in solving problems of uncertainty, imprecision and partial truth, including in the field of health [5].

According to Dr. Johanes Chandrawinata, MND, SpGK, health risk trends move from the traditional risks (malnutrition, hygiene sanitation, etc.) to modern risk (Obesity, diabetes, cholesterol, etc. Dr. John, nutritionist RS. Borromeus Bandung revealed, transition lifestyle changes have made 10 diseases are a major killer in Indonesia, especially the urban citizen, he said when MoU Kalbe Farma with Tipco in Jakarta. he detailed, ten diseases are : stroke (19.4 percent), diabetes mellitus (9.3 percent), hypertension (7.5 percent), TB (7.3 percent), heart iskesmik (6.5 percent), malignant tumors (5.8 percent) , liver disease / liver (5.5 percent), NEC (5.3 percent), other heart diseases (5.1 percent), and chronic lower respiratory disease (4.7 percent), [1].

Diagnosis of diabetes mellitus is usually done by a specialist with attention to physical symptoms, the patient's complaints and the results of laboratory tests.

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It is hoped there is simple application that can be implemented efficiently and effectively to diagnose diabetes mellitus so that a common people can perform early diagnosis and immediate treatment.

2. Literature Review

Generally, the expert system is a system that adopts human knowledge into a computer so that the computer can be used to solve a problem, as was done by an expert. Expert systems are made on specific knowledge areas and for a certain skill approaching human capabilities in one specialized field. Expert systems try to find a satisfactory solution as did an expert and provide an explanation for the measures taken and give the reasons for the conclusions drawn [4].

Puskesmas are functional organizations that conduct health efforts are comprehensive, integrated, equitable, acceptable and affordable to the public. The health efforts conducted to prioritize the services to the public in order to achieve optimal health, without ignoring the quality of services to individuals.

Diabetes Mellitus is classified into two types : DM depend on insulin (type 1 DM) and DM not depend on insulin (DM type 2). DM type 1 usually inflict symptom before patients age 30 years, although indication can appear at any time. Patients DM type 1 need insulin from outside the body to survival. DM type 2 usualy happened when patients age 30 years or older, and patients are not depend on insulin from outside the body, except in certain condition. Most cases are DM type 2 which commonly found in people who are obese or overweight due to lifestyle they have done. while, DM type-1 more influenced by heredity factors, although hereditary factors contribute to the risk of DM only 5%. Moreover, there are DM who known which Gestational DM that occur during pregnancy, caused by impaired glucose tolerance in these patients [8].

2.1 Fuzzy Inference System (FIS) Mamdani

Prior to the theory of fuzzy logic is known a crisp logic which has a value of true and false explicitly. otherwise, Fuzzy logic is a logic that has a value of vagueness or ambiguity (fuzzyness) between true and false. In the theory of fuzzy logic a value could be true and false simultaneously. But how much truth and falsity of a value depending on the weight of its membership. But how much truth and falsity of a value is depended on the quantity of its membership. People who are not familiar with fuzzy logic would have thought that fuzzy logic is a very complicated and unpleasant. However, once people know it, he would be very interested and will be newcomers to participate studying fuzzy logic. Fuzzy logic is said to be a new logic of the pass, because the science of modern and new methodical fuzzy logic are discovered a few years ago. when in fact the concept of fuzzy logic itself is already in us for a long time [4].

Mamdani method is often also known by the name of Max-Min method. This method was introduced by Ebrahim Mamdani in 1975. To get the output, required four stages:

- Formation of fuzzy set. the first step of fuzzification process is determine the fuzzy variables and fuzzy sets. Then specify the degree of membership between fuzzy input data and fuzzy sets that have been defined for each system input variables of each fuzzy rule. In mamdani method, both the variable input and output variables are divided into one or more fuzzy sets.
- Application function implication mamdani method. Function application used is min. The results of fuzzy implications of each of these rules then combined to produce an output fuzzy inference.
- Composition Rules (rule). Unlike the monotonous reasoning, if the system consists of several rules, then inference derived from the collection and correlation between rules. There are three methods used in performing fuzzy inference system, namely: max, additive and probabilistic OR.
- Assertions (defuzzy). Input from defuzzification process is a fuzzy set that obtained from the composition of fuzzy rules, while the resulting output is a number of fuzzy set domain [6].

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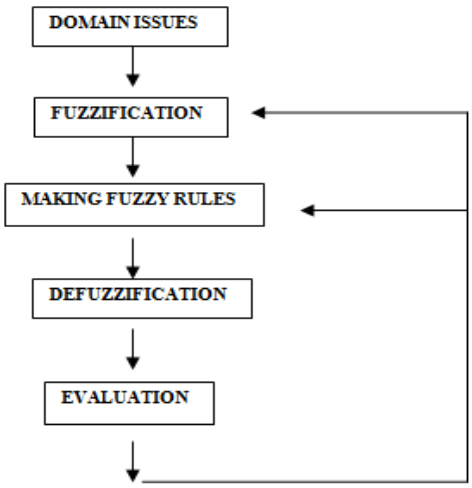

Figure 1. Development of Fuzzy Inference System Mamdani

2.2 Matlab Toolbox: Fuzzy

In order to use fuzzy logic functions that exist in Matlab, it must be installed on Fuzzy Toolbox first. *Fuzzy Logic toolbox (FLT)* provides Graphical User Interface facilities (GUI) to simplify the building, editing, and observing fuzzy reasoning system, namely:

- Fuzzy Inference System (FIS) Editor
- Membership Function Editor
- Rule Editor
- Rule Viewer
- Surface Viewer [3].

3. Method

The research that implemented is the kind of experimental research that makes the application of Fuzzy Inference System (FIS) Mamdani in diagnosing diabetes mellitus based on the results of laboratory tests.

Expert systems Fuzzy Inference System (FIS) Mamdani research flow in the diagnosis of diabetes mellitus will follow the stages of the research activities through several stages in its development, namely :

3.1 Preliminary research

Activities performed during the preliminary research is collect the materials of literature that related to the title of the research. then the next step is collection of secondary data in Puskesmas. Based on the data will be obtained some of the criteria that used for the further research.

3.2 Data

Sample data that used in this research is secondary data from Puskesmas in East Jakarta. The object of research is data of patients with diabetes mellitus. Taken as many as 200 patients who consisting of 100 patients with diabetes mellitus dan 100 patients without diabetes mellitus who randomly selected from 200 patients with diabetes and 200 patients without diabetes mellitus.

From 200 cases, 120 cases (60%) were used as training data, 80 cases (40%) were used as testing data. Training data to develop applications, and testing data is used to apllicatins testing.

3.3 Data processing

Data will be processed using the approach of Fuzzy Inference System (FIS) Mamdani with supported by matlab toolbox.

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Table 1. Fuzzy Variable Sets

Function	*Variable*	*Range*
Input	*Plasma Glucose Concentration a 2 hours*	*[0 – 10]*
	Diastolic Blood Pressure (mm Hg)	*[0 – 10]*
	Body Mass Index	*[0 – 10]*
	Diabetes Pedigree Function	*[0 – 10]*
	Pregnant	*[0 – 10]*
Output	*Laboratory test score*	*[0 – 10]*

3.4 Data Collection Methods

This research was conducted to produce the necessary data and information and to connect with the things that will be written. The collection of data and information conducted using the method of collecting primary and secondary data from the Puskesmas in East Jakarta.

3.5. Research Instrument

- This research uses primary and secondary data of diabetes mellitus which used as instrumentation to obtain data in process of diseae diagnosis.
- Data is presented in the form of tablature models and variables each of the 100 diabetes patients and 100 non diabetes mellitus patients.
- To analyze data, this research uses Fuzzy Inference System (FIS) Mamdani with matlab Toolbox and Graphical User Interface (GUI).

3.6 Data analysis technique

Data analysis use quantitative with the rules of mathematics to the data numbers or numerical. Fuzzy set in the input and output variables are divided into one or more fuzzy sets. Application function implications are used for each rule is a function min. Defuzzification use the facilities on the matlab toolbox with fuzzy mamdani method.

3.7 Steps of The Research Process

Steps of research are development of *Fuzzy Inference System* (FIS) Mamdani, consist of:

3.7.1 Problem domains

- The feasibility of a problem is not resolved or difficult when value is crisp
- Therefore, proposed a fuzzy-based problem-solving approach
- At this step it is also determined fuzzy variables that will be used in the system.

3.7.2 Fuzzification

- This step is convert crisp values into linguistic variables.
- At this step all of fuzzy variables should be made into fuzzy sets.
- Generally use some curves as a fuzzy representation of a variable. For example: Triangular curve, trapezoidal curve, curve Gausian.

3.7.3 *Fuzzy Rules*

- *Fuzzy* rules are made for mapping inputs to ouput.
- Known as *if-then fuzzy*

- Making the rules should be carried out together with experts.

3.7.4 Defuzzification

- Defuzification is done to get back the crisp values of a number of rules that have been made
- Will depend on the method of reasoning used: Mamdani

3.7.5 Evaluation

- The evaluation is done to test the output of the resulting application
- Evaluation could be in two ways :
  1. With Experts : by providing a combination of inputs to the experts to then experts asked to assess the results and are matched to the system
  2. Without Experts : if we have data test [2]

4.Result

4.1 Grouping Data

For the selection of a sample of patients with Diabetes Mellitus (DM), secondary data from Puskesmas. The object of research is data of 100 Diabetes Mellitus patients and 100 non Diabetes Mellitus patients, which consists of five input variables and one output variable. This research aims to make a diagnosis of Diabetes Mellitus applications using Fuzzy Inference System Mamdani method.

Table 2. Variable and Category Value

No	*Variable*	*Value*	*Clasification*	*Domain*
1	*Plasma Glucose Concentration a 2 hours*	*187 – 232*	*Abnormal*	*[6 10]*
		141 – 186	*Medium*	*[3 7]*
		44 – 140	*Normal*	*[0 4]*
2	*Diastolic Blood Pressure (mm Hg)*	*92 – 122*	*Abnormal*	*[6 10]*
		81 – 91	*Medium*	*[3 7]*
		30 – 80	*Normal*	*[0 4]*
3	*Body Mass Index*	*34 – 67*	*Abnormal*	*[6 10]*
		26 – 33	*Medium*	*[3 7]*
		18 -25	*Normal*	*[0 4]*
4	*Diabetes Pedigree Function*	*0.54 – 2.29*	*Abnormal*	*[6 10]*
		0.50 – 0.53	*Medium*	*[3 7]*
		0.08 – 0.49	*Normal*	*[0 4]*
5	*Pregnant*	*10 – 17*	*Abnormal*	*[6 10]*
		5 – 9	*Medium*	*[3 7]*
		0 – 4	*Normal*	*[0 4]*

4.2 Preliminary Research

In the preliminary research conducted data sharing, ie 60% as training data, 40% as testing data. After that, the steps are the development of Fuzzy Inference System Mamdani method.

4.3 Research Results

Data from laboratory tests of patients with Diabetes Mellitus as many as 200 cases , there will be fuzzy variables in the diagnosis of Diabetes Mellitus disease using matlab toolbox.

There are five criteria that will be analyzed and used as fuzzy variables in the diagnosis of Diabetes Mellitus, namely:

1. Plasma Glucose Concentration a 2 hours

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Plasma Glucose Concentration a 2 hours variables divided into three fuzzy sets, namely: NORMAL, MEDIUM, and ABNORMAL. NORMAL fuzzy set has a domain [0,4] where the highest degree of membership NORMAL (=1) is located on the numbers 0-3. MEDIUM fuzzy set has a domain [3,7] where the highest degree of membership MEDIUM (=1) is located on number 5. ABNORMAL fuzzy set has a domain [6,10] where the highest degree of membership ABNORMAL (= 1) is located on a number ≥ 7. Plasma Glucose Concentration a 2 hours variable is represented by a triangular membership function.

2. Diastolic Blood Pressure
   Diastolic Blood Pressure variables divided into three fuzzy sets, namely: NORMAL, MEDIUM, and ABNORMAL. NORMAL fuzzy set has a domain [0,4] where the highest degree of membership NORMAL (=1) is located on the numbers 0-3. MEDIUM fuzzy set has a domain [3,7] where the highest degree of membership MEDIUM (=1) is located on number 5. ABNORMAL fuzzy set has a domain [6,10] where the highest degree of membership ABNORMAL (= 1) is located on a number ≥ 7. Diastolic Blood Pressure variable is represented by a triangular membership function
3. Body Mass Index
   Body Mass Index variables divided into three fuzzy sets, namely: NORMAL, MEDIUM, and ABNORMAL. NORMAL fuzzy set has a domain [0,4] where the highest degree of membership NORMAL (=1) is located on the numbers 0-3. MEDIUM fuzzy set has a domain [3,7] where the highest degree of membership MEDIUM (=1) is located on number 5. ABNORMAL fuzzy set has a domain [6,10] where the highest degree of membership ABNORMAL (= 1) is located on a number ≥ 7. Body Mass Index variable is represented by a triangular membership function.
4. Diabetes pedigree function Variable
   Diabetes pedigree function Variable is divided into three fuzzy sets are: NORMAL, MEDIUM, and ABNORMAL. NORMAL fuzzy sets have the domain [0,4] where the highest degree of membership NORMAL (= 1) is located on the numbers 0-3. MEDIUM fuzzy set has a domain [3,7] where the highest degree of membership MEDIUM (= 1) lies in the value of 5.
   ABNORMAL fuzzy sets have a domain [6,10] where the highest degree of membership is ABNORMAL (= 1) is located on a number ≥ 7. Diabetes pedigree function variable is represented by a triangular membership functions.
5. Pregnant Variable
   Pregnant variable is divided into three fuzzy sets are: NORMAL, MEDIUM, and NOT NORMAL. NORMAL fuzzy sets have the domain [0,4] where the highest degree of membership NORMAL (= 1) is located on the numbers 0-3. MEDIUM fuzzy set has a domain [3,7] where the highest degree of membership MEDIUM (= 1) lies in the value of 5.ABNORMAL fuzzy sets have a domain [6,10] where the highest degree of membership is ABNORMAL (= 1) is located on a number ≥ 7. Pregnant variable is represented by a triangular membership functions

4.4 Mamdani Process

4.4.1 Fuzzification

The function degree of membership that used is a triangle function.
Triangle function:

$$\mu[x] = \begin{cases} 0 & x \leq a \; atau \; x \geq c \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{b-x}{c-b} & b \leq x \leq c \end{cases}$$

4.4.2 Making Fuzzy Rule

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The knowledge base in designing this application is necessary, which contain rules or rule that is useful in the decision as a result of the system output. The design of these rules is a step after the formation of fuzzy set.

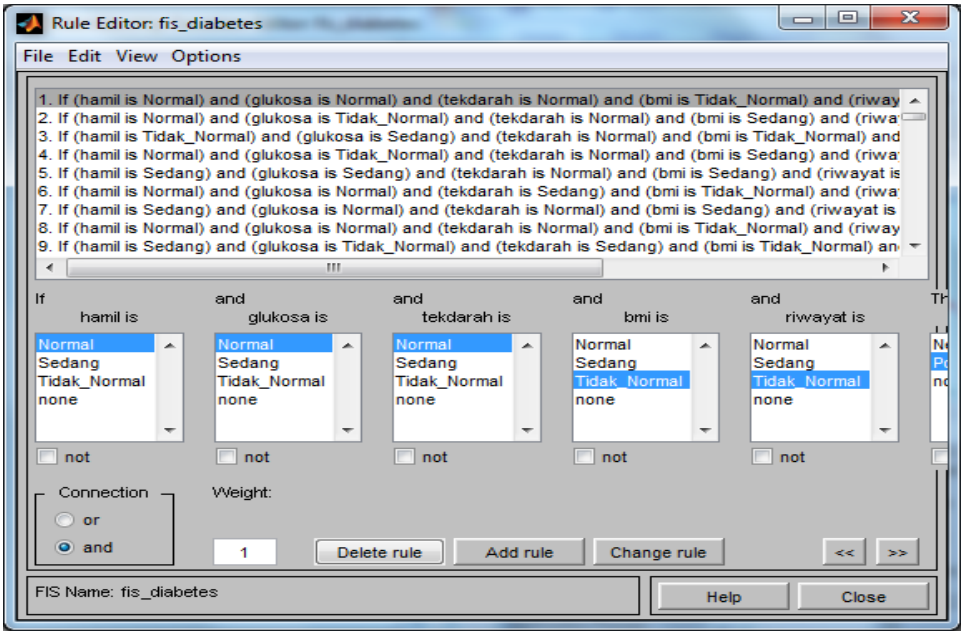

Figure 2. Rule Editor Diabetes Mellitus

The rules have been compiled based on the decisions of doctors as specialists can later be used as a decision-making in the diagnosis of diabetes mellitus.

4.4.3 GUI Diagnosis of Diabetes Mellitus

After the process of inputting data is complete, it be done the process of diagnosing diabetes mellitus which will produce output positive or negative diabetes mellitus. Here is a GUI (Graphical User Interface) for the diagnosis of diabetes mellitus.

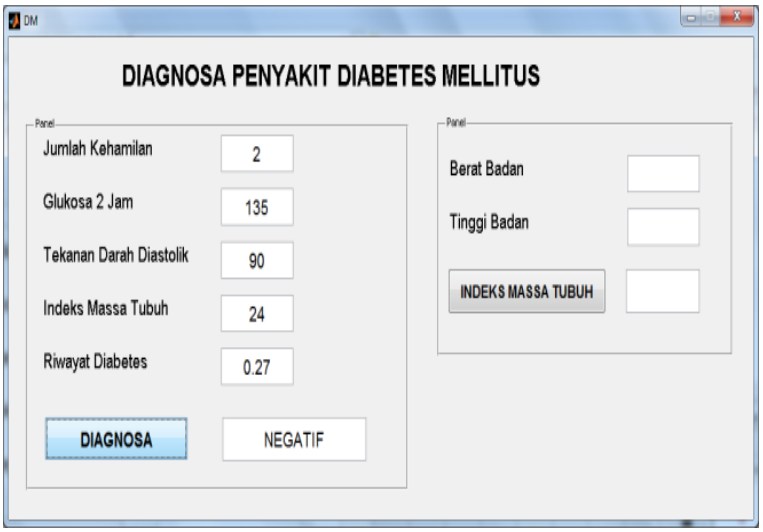

Figure 3. GUI Diagnosis of Diabetes Mellitus

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Result of the analysis will be tested laboratory test data of patients with diabetes and without diabetes mellitus. The data is the data sekunder from six Puskesmas in East Jakarta.
The trial was conducted to determine the accuracy of the output application and to determine the extent to which the application's ability to detect diabetes mellitus. The eighty data is testing in trials with parameters different laboratory test results, it was found that:
1. The value of each parameter influence on the results obtained.
2. Rule that has created an effect on the rule evaluation process that occurs, the more precise rule made the results obtained will be more accurate.
3. Rule created just for diagnosing diabetes mellitus to see the results of laboratory tests, due to getting optimal results requires a more complete reasoning of experts.
4. The ability of applications in diagnosing diabetes mellitus is used to obtain health information diabetes mellitus so patients can take immediate preventive measures in the prevention or early treatment.
5. The result is an expert system for diagnosis of Diabetes Mellitus by using Fuzzy Inference System (FIS) Mamdani method, obtained an accuracy rate of 95%.

5. Conclusions

Based of the research results, it can be concluded : Diagnosis of diabetes mellitus can be built with the approach of fuzzy logic, determining a diagnosis with a decision support system using the approach of fuzzy logic is more objective than the diagnosis of disease manually, determining a diagnosis with a decision support system using the approach of fuzzy logic is more effective and efficient, the determination of disease diagnosis with fuzzy logic approach uses five criteria to determine the decision. The function of this application is to facilitate the public and clinicians in the diagnosis of diabetes mellitus was quick and efficient.

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